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PATENT SPECIFICATION

719,687

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COMPLETE SPECIFICATION

Improvements in or relating to Electrostatic Machines

I, NOEL JOSEPH FELICI, a French Citizen, of 29, Avenue Felix Vialet, Geroble (Isere), do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to electrostatic machines constructed with a conveyor member for conveying the electrostatic charges, this conveyor member being made of an insulating material and being rotatably or otherwise mounted for relative movement with respect to conductive electrodes. The conveyor and electrodes are disposed in a medium having a high dielectric strength, such as a pressurised gas, the electric charges being first deposited on the conveyor by an element which causes ionising of the dielectric medium and thereafter being picked up by another charge collecting element for delivery to the machine terminal.

A number of such machines have been proposed and some have been constructed heretofore but their low power and poor efficiency have not been favorable to their industrial utilisation.

An object of the present invention is to provide an electrostatic machine of the above type having a high power per unit of volume and weight and to this end the invention preferably provides a cylindrical arrangement of rotatable and fixed parts.

Another object of the invention is to provide an electrostatic machine which is simple to build and consequently of low cost.

Still another object of the invention is to provide an electrostatic machine dispensing with frictional contact of conductive parts, such as contact between brushes and collectors, which are subject to wear and which cause the production of conductive dust which may lead to leakage currents or to short circuits.

A further object of the invention is to provide machines of the above mentioned type in which a high voltage, that is, a large increase in potential of the charge carried by the conveyor, may be secured in the movement of this conveyor between the position in which the charge is deposited thereon and the position in which the charge is discharged to the terminal of the machine.

A still further object of the invention is to provide in a machine of the type referred to for a considerable reduction of losses due to friction of the members moving in a dielectric fluid and due to turbulence developed in this fluid.

In order to achieve these objects an electrostatic machine according to the invention comprises fundamentally at least one conveyor member of insulating or dielectric material capable of withstanding a high flux density of the electric field, this conveyor having two parallel faces providing even, regular surfaces and being supported in relation to a conductive electrode for movement of one relative to the other in the direction parallel to the faces of the conveyor. The conveyor is of such form and disposition that successive adjacent portions thereof are moved into and out of face to face relation to each electrode in succession of at least one pair of electrodes. Each of the electrodes of the pair has a surface substantially parallel with the faces of the conveyor when in face to face relation thereto, each electrode also having a substantial extent of this surface perpendicular to the direction of relative movement of the conveyor and the electrode with respect to each other. One of the electrodes of the pair which may be called the exciter electrode is electrically connected to a terminal of an auxiliary

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source of potential difference while the other electrode of the pair which may be called the screen is connected with the insulated or output terminal of the machine. The other terminal of the source may be connected to ground.

Co-operating with the conveyor and the electrodes are two elements a given one of which acts to ionize the dielectric fluid and the other acts as a collector of the electric charges conveyed by the conveyor. It is a feature of the invention that these elements are formed as thin elongated members extending perpendicular to the direction of relative movement of the conveyor and the conductive electrodes, these elements being disposed at the opposite face of the conveyor from the electrodes parallel to this other face and as close as possible thereto, these elements respectively being disposed opposite the two electrodes of the pair of electrodes above referred to.

In order to provide the electric field and to produce the ionisation of the dielectric medium as about to be described, one of the electrodes of the pair is maintained at a predetermined potential by connecting this electrode to a terminal of an auxiliary source of potential difference the other terminal of which may be connected to ground, as above mentioned. The electric field is established between the exciter electrode and the ionisation element above mentioned, this element being connected to ground. As the ionisation element is disposed at the opposite side of the conveyor from the exciter electrode of the pair of electrodes, it will be understood that the conveyor is moved in the direction generally transverse to the lines of force of the electric field. The extent of the conveyor is continuous in the direction of the relative movement thereof with respect to the electrodes and its active surfaces are continuously moved through this field. This ionisation element is of such form that the free surface thereof is restricted and a high concentration of the electric field thereon is produced. The gaseous dielectric medium in which this ionising element and the conveyor are disposed is ionised, this medium being in contact with the adjacent surface of the conveyor member, that is, the surface which is at the opposite side of the conveyor from the exciter electrode. The ionisation which thus takes place causes ions carrying a given electric charge to migrate to the adjacent face of the conveyor upon which these ions are carried forward in the movement of the conveyor relative to the electrodes toward the position of the other electrode which is disposed in spaced relation to the exciter electrode and which, as above stated, is connected to the output terminal of the machine. At the same side of the conveyor at which the ionising element is disposed and opposite to this other electrode of the pair of electrodes is disposed the collector element above mentioned to which the charges carried by the ions upon the surface of the conveyor are discharged, these electric charges being conducted to the output terminal of the machine through a suitable conductor.

It is a feature of the invention that the ionising element and the charge collecting element both provide a surface of small radius facing the conveyor, such as may be provided by wires or by thin blades disposed edgewise to the face of the conveyor. These wires or blades have their length extending transversely of the direction of relative movement of the conveyor with respect to the electrodes. The ionising and collecting elements both are disposed as close as possible to the adjacent face of the conveyor while avoiding contact therewith. The gaseous dielectric material is effective to prevent passage therethrough of current directly from one element to the other, so that as the relative movement of the conveyor and electrodes is produced the potential of the charges carried by the ions which are transported by the conveyor at its surface is increased from the potential at the ionising element to the potential of the load or output terminal.

It is another feature of the invention that a member of low conductivity or high resistivity electrically connecting the two electrodes of the pair of electrodes is disposed in the space between each electrode and the conveyor, this member providing at the face thereof adjacent the conveyor an even, regular surface. This member may be of a homogeneous material having a resistivity, for example, of the order of 10^{10} to 10^{11} ohms per cm per cm^2 and serves to avoid field concentrations and uniformly to distribute the gradient of the potential difference existing between the two electrodes of the pair of electrodes. This member also may be formed of an insulate material covered with a layer of high resistivity material in contact with the electrodes or it may be provided by a layer of high resistivity material deposited on the support of insulating material which supports in common the two electrodes. In any of these forms the thickness of the high resistivity layer must be substantial, a thin coating of the material being insufficient.

It may be shown that where the member of high resistivity is provided with sufficient thickness and of proper resistivity the potential difference between the electrodes may be established along a smooth gradient and the longitudinal field parallel

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to the movement of the conveyor may be substantially constant. It also may be shown that in the region adjacent the faces of the conductive electrodes the potential will be substantially uniform along these faces in the direction of movement of the conveyor and that the zones which are adjacent the edges of the electrodes which extend transversely of the conveyor movement provide for gradual rather than abrupt change from the zone of uniform potential to the gradient of potential in the direction toward the other electrode of the pair of electrodes.

It is a feature of the invention that the medium surrounding the ionising and collecting elements and in contact with the face of the conveyor which faces these elements should have a high ionic mobility while providing sufficient dielectric strength to prevent breakdown therethrough between any of the conductive parts that are at high potential difference. This medium may be provided, for example, by certain gases under high pressure of the order, for instance of 10 to 30 kg. per square centimeter. Such a gas, for example, may be very pure nitrogen or hydrogen, preferably very free of electronegative impurities which may act to fix the electrons, such as oxygen and chlorine which heretofore have been used. Pure hydrogen is particularly advantageous because it provides a very high mobility of the ions while affording adequate dielectric strength.

The space between the two electrodes and the conveyor at the side thereof opposite to the ionising and collector elements in which a very intense electric field prevails should be filled with a dielectric fluid medium having a high dielectric strength and preferably a high dielectric constant. This dielectric medium, therefore, may be and preferably is different from the dielectric medium at the opposite face of the conveyor. As high ionic nobility of this second medium is not necessary, it may be provided, for example, by a gas such as nitrogen or oxygen, or other electro-negative gases such a freon, or a liquid medium. For practical reasons, however, it may be advantageous to enclose the whole machine in a sealed envelope filled with a single dielectric medium meeting these requirements to the requisite extent, especially as to the provision of high ionic mobility, the shaft or other driving member for effecting the relative movement of the conveyor or conveyors and the electrodes passing through a stuffing box in this envelope where, as in the usual case, the medium is a gas under pressure.

When the machine is required to supply large currents, the insulating material of which the conveyor or conveyors are made should be capable of withstanding without danger of breakdown an electric flux density (product of the dielectric constant of the material and the electric field intensity) as high as possible. The dielectric constant of the material, which may be a ceramic material or a synthetic resin, advantageously is from 4 to 10 times that of the fluid medium in the space between the conveyor and the conductive electrodes.

The spacing of the ionising and collector elements from the conveyor is made as small as possible without allowing these elements to touch the conveyor. The dielectric material in which these elements are disposed prevents passage of the current from one element to the other and to the supporting parts. The small spaces, however, insure that the resistance to the current flow, which in the normal operation of the machine occurs by virtue of the conveyance of the charge carrying ions upon the surface of the conveyor, shall be as low as possible. Because of the geometric mechanical form of the relatively moving parts of the electrostatic machine of the invention such small clearances may be maintained between these parts. Moreover, the space between the high resistivity material and the adjacent face of the conveyor may be made very small and it may be shown that such reduction of the space decreases the possibility of discharge along the surface of the conveyor, advantage being taken of the fact that the dielectric strength of the intervening medium is increased as the space between the two parts at different potentials is decreased.

Two embodiments of machines according to the invention are described hereinafter by way of example with reference to the appended drawings in which:—

Fig. 1 is a longitudinal, sectional view of such a machine through line I—I of Fig. 2;

Fig. 2 is a cross sectional view of said machine through line II—II of Fig. 1;

Fig. 3 is a diagram showing the operation of the machine;

Fig. 4 is a diagram of the electrical connections for the machine of Figs. 1 and 2;

Fig. 5 is a longitudinal, sectional view of a second embodiment through line V—V of Fig. 6;

Fig. 6 is a cross sectional view of this machine through line VI—VI of Fig. 5.

Referring now to Figs. 1 and 2, the machine according to the invention comprises a sealed cylindrical envelope 1 capable of withstanding an internal pressure of several tens of atmospheres, and which may be filled, for example, with pure hydrogen under a pressure of, say, 10 to 20

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kg. per sq. cm. For the sake of simplicity, only the portion of this envelope which surrounds the essential parts of the machine has been shown.

At one end of the envelope 1 a bell-shaped metal support 3 is secured by means of insulators 2, this support comprising a protruding part 4 on which is attached an insulating flange 5. On a circumferentially machined portion 6 of said flange is fitted a tubular, cylindrical part 7 made of insulating material in the inner cylindrical face of which are provided four longitudinal grooves 8 located in pairs on two perpendicular diameters. In two of these grooves that are diametrally opposite to each other are disposed two longitudinal metal members 9 which constitute the excitation electrode while electrode members 10 similar to members 9 are secured in two other grooves 8 located on the perpendicular diameter. The members 10 act as screens or shields.

A cylindrical sleeve 11 of substantial thickness made of a high resistivity material, of the order of 10^{10} to 10^{11} ohms per centimeter per square centimeter, provided for instance, by a high resistivity synthetic resin or by a ceramic, is fitted inside the tubular part 7 and in contact with excitation electrodes 9 and screen electrodes 10.

A second hollow member 12 of a generally cylindrical shape is attached to the tubular part 7 co-axially therewith by means of co-operating circumferentially machined bearing surface 13. The member 12 also comprises, on its outer face, longitudinal grooves 14 which respectively face the grooves 8 in member 7. Metal blades 15 facing the electrode 9 and metal blades 16 facing the screens or shields 10, respectively, are secured at the bottom of these grooves 14 in the member 12. Resilient tensioning members 17 are arranged at each end of the blades 15 and 16 for supporting, in each corresponding groove and substantially at the level of the periphery of member 12, two metal wires 18, 19 which extend parallel with the axis of the machine. These pairs of metal wires are stretched by the tensioning members in the grooves 14 facing the electrodes 9 and 10 and serve as the ionising and collecting elements.

Within the space between sleeve 11 and member 12 is disposed the skirt of a hollow, cylindrical, bell-shaped insulating member 20 open at one end of the cylinder. This member 20 constitutes the conveyor. The conveyor 20 is keyed on a rotary shaft 21 extending along the axis of the machine and supported, on the one hand, by a ball bearing 22 housed in part 4 of support 3 and, on the other hand, by similar bearings 23 housed in a sheath 24 held in a support 25 connected with member 12 through webs 25a. Shaft 21 is connected through an insulating coupling 21a with a second shaft, not shown, which passes through the sealed envelope by means of a stuffing box and which may be driven in rotation by any suitable means such as an electric motor.

Electrodes 9 are electrically connected by conductors 26 to one of the terminals of a source of potential, such as an auxiliary electrostatic generator 27 (Figs. 3 and 4) which charges these electrodes at a predetermined potential, the other terminal of this source being grounded. Ionising elements 18 are grounded through conductors 28. On the other hand, the shields 10 and ionising elements 19 are electrically connected through conductors 29 to the output terminal 30 of the machine (Figs. 3 and 4). Conductors 26, 28 and 29 pass through suitable insulating bushings in envelope 1. When the envelope 1 is made of metal it is advantageously grounded, in which case conductors 29 may be directly connected therewith.

The operation of the above described machine is explained hereinafter, reference being had to the diagram of Fig. 3 which represents, in developed form, an exciter electrode 9 and a shield 10 spaced therefrom in the direction of movement of conveyor 20 a fragmentary portion of which and of the high resistivity sleeve 11 are shown, as well as the ionising element 18 and the collector element 19 which are spaced in the direction of movement of the conveyor, together with the corresponding electrical connections.

Exciter electrode 9 being raised by the auxiliary generator 27 to a potential $-V$ with respect to ground, an intense electric field is established adjacent ioniser 18 which is grounded and which faces electrode 9. As a result, positive charges are deposited on the face 20′ of insulating conveyor 20 which is disposed toward ioniser 18. In the space between electrode 9 and the section of the other face 20″ of the conveyor 20 which is facing electrode 9, ionisation is produced which is much less intense but it is sufficient for negative charges to be deposited on the face 20″ of the conveyor 20.

During the movement of a section of the insulating conveyor 20 from the position facing the exciting electrode 9 towards shield electrode 10 in the direction of the arrow, Fig. 3, the potential of the charge carried by this section increases. When this section comes to the position facing collector element 19 this charge flows through collector 19 and charges the insulated term-

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inal 30 of the machine and the shield 10 which are thus raised to a potential $+U$. It may be shown that the amount of charge, due to the presence of negative charges on the outer face 20″ of the insulating conveyor 20, is greater than if these negative charges did not exist and, as a result, that after a certain time of operation, an equilibrium is reached between the contribution and the losses of these negative charges and the machine operates in such a manner that the conveyor takes negative charges from the outer circuit and thus operates by "double conveying," although its shield electrodes are only at potential $+U$.

A condition to be obtained for such operation is that the insulating material forming the conveyor 20 shall be able to withstand a dielectric stress double that to which it would be subjected if the electrodes were maintained at potentials $-V/2$ and $U+V2$.

A purpose of the high restivity sleeve 11 is to avoid field concentrations on the lateral edges *9a*, *10a* of the electrodes and shields and to distribute uniformly the gradient of the potential difference existing between an inductor 9 and the next shield 10 in such a manner that the charges deposited on the conveyor move in a well-distributed longitudinal field, building up and discharging gradually in the vicinity of the electrodes. Instead of being made as a whole of high resistivity material, this sleeve may comprise an insulating material, the outer face of this sleeve which is in contact with the electrodes being covered with a layer of high resistivity material, such as a high restivity glass of substantial thickness. This sleeve 11 may also be formed by coating the inner faces of part 7 and of the electrodes 9 and 10 with a layer of high resistivity material of substantial thickness.

The gap between sleeve 11 and the outer face 20″ of conveyor 20 should be as small as possible in order to decrease the possibility of discharge over and along the surface of the conveyors in normal operation. This space may be, for instance, of the order of 0.1 to 0.5 mm, taking into account the dielectric strength of the fluid medium occupying this space, which strength should be sufficiently high for avoiding discharges between the conveyor and inductor.

The cylindrical shape adopted in the above-described embodiment makes it possible to obtain a compact, simple and economical construction. Due to the fact that cylindrical surfaces are relatively easy to machine with precision, fluctuations or breakdown due to variations in the distance between the conveyor and the electrodes and between the conveyor and the ionisers and collectors are avoided, which fluctuations have been recognised heretofore as affecting the operation of the machine unfavorably in machines with flexible conveyors.

In the machine shown in Figs. 1 and 2 the exciting electrodes and screen or shield electrodes are disposed exteriorly of the conveyor while the ioniser and collector elements are located within the hollow space of the conveyor. The converse arrangement also is possible, as shown in Figs. 5 and 6.

In Figs. 5 and 6 identical or similar parts to those of the machine in Figs. 1 and 2 are designated by the same reference numerals increased by 100. Thus, the machine again comprises a sealed envelope 101, insulators 102 securing a support 103 on part 104 to which is fitted flange 105 which, by means of the cylindrical bearing surface 106, supports the cylindrical member 107. The insulating conveyor 120 is keyed on the shaft 121 rotatably mounted in the bearings 122 and 123, the bearings 123 being housed in the ring 124 carried in the support 125 connected with the inner cylindrical part 112 through webs *125a*.

In contrast to the machine of Figs. 1 and 2 it is the outer cylindrical member 107, portions of which are formed as side flats, which carries the ioniser and collector elements. These elements in this embodiment are formed of thin metal blades 118 and 119, respectively disposed on edge in two perpendicular diametral planes of the machine. These blades are supported by insulating rods 131 held at their ends in member 107.

Moreover, it is the inside cylindrical part 112 which carries the electrodes 109 and 110 and on which is fitted the high resistivity sleeve 111. The assembling of member 112 and of the other parts supported by this member is made easier and the whole is made lighter by forming depressions in the outer circumference of the part 112 in order to provide machined bosses, such as 112′ and 112″, arranged in rows lengthwise and circumferentially of the part 112, on which bear respectively the exciter electrodes 109, the shields 110 and the high conductivity sleeve 111, the free interstices between the bosses being filled with a cast compound which may consist of coal tar pitch, insulating synthetic resin or an insulating liquid.

The centering of member 112 and of the parts carried by this member is accomplished in relation to shaft 121 the end of which is supported by a bearing 132 housed in a flanged head 133 fitted into member 107, one or more longitudinal ribs 134 being provided on this head engaging corre-

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sponding grooves in member 112 for preventing rotation of the member 112 relative to the head 133 and bearing 132.

The construction of this machine, the operation of which is the same as that of the machine of Figs. 1 and 2, makes the necessary insulation easier. In addition, the adjustment of the positions of the ioniser and collector elements 118 and 119 is made easier due to the fact that they are located on the outside and are, therefore, more easily accessible.

The two above-described embodiments relate to cylindrical machines, but it will be appreciated that a machine according to the invention might also comprise one or more disc-shaped conveyors of insulating material, the inductors and shields, on the one hand, and the ioniser and collector elements, on the other hand, being arranged radially at the respective sides of each disc.

Although the machines of the invention have been described as operating as generators it will be understood that they can also operate as motors, a potential +V being applied to the shields 10 or 110 and to the collectors 19 or 119 and an excitation potential −V being applied to the inductors 9 or 109.

What I claim is:—

1. An electrostatic machine, comprising at least one pair of conducting electrodes which respectively act as an exciter electrode and as a screen, an ionising element arranged opposite to and spaced from said exciter electrode, a collecting element arranged opposite to and spaced from said screen, and a rigid conveyor member of insulating material positioned in the space between said conducting electrodes and ionising and collecting elements and mounted for movement relative to and between the opposing electrodes and elements in turn, wherein the space between the ionising and collecting elements and the surface of the conveyor member is filled with compressed hydrogen or nitrogen, and the surfaces of the conducting electrodes which face the conveyor member are completely covered to at least beyond their edges, with high resistivity material.

2. An electrostatic machine comprising at least one cylindrical conveyor member for electric charges, made of a rigid dielectric material and providing at opposite faces thereof parallel true surfaces, the said conveyor member being arranged for relative movement with respect to at least two elongated conducting electrodes extending transversely to the direction of said relative movement and each having a surface extending substantially parallel to one face of the conveyor member one of the said conducting electrodes being arranged for electrical connection with one of the terminals of an auxiliary source of potential and the other conducting electrode being electrically connected to a terminal of the machine, at least one ionising element and one collecting element formed of narrow elongated members arranged closely adjacent to and parallel to the other face of the conveyor member, and respectively opposite the two conducting electrodes, the ionising element which is opposite the electrode connected to the auxiliary source being adapted to be electrically connected to the other terminal of said source and the collecting element which is opposite the electrode connected to a terminal of the machine being connected to the same terminal, the surfaces of the conducting electrodes which face the conveyor member being entirely covered to at least beyond their edges with high resistivity material.

3. An electrostatic machine as claimed in Claim 1 or 2, in which the high resistivity material extends between the two conducting electrodes forming a potential gradient member therebetween.

4. An electrostatic machine, comprising a rigid cylindrical conveyor member of insulating material mounted for rotation relative to and in succession past at least one pair of conducting electrodes acting respectively as an exciter electrode and as a screen, each conducting electrode being arranged adjacent one surface of the conveyor member but spaced therefrom, a cylindrical layer of high resistivity material arranged in said space and extending between the conducting electrodes to form a potential gradient member therebetween, an ionising element arranged opposite the exciter electrode, a collecting element arranged opposite the screen electrode, said ionising and collecting elements being positioned adjacent the other surface of the conveyor member, and the space between the elements and the conveyor member being filled with substantially pure nitrogen or substantially pure hydrogen under pressure.

5. An electrostatic machine as claimed in Claim 2, 3 or 4, wherein the conducting electrodes are arranged adjacent the inner surface of the conveyor member and the ionising and collecting elements are arranged adjacent the outer surface of the conveyor member.

6. An electrostatic machine according to Claim 3, 4 or 5 in which the potential gradient member connecting the conducting electrodes is formed of a continuous, homogeneous piece of a material having a high resistivity.

7. An electrostatic machine as claimed in Claim 3, 4 or 5, in which the potential gradient member connecting the conducting

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electrodes is formed of a continuous piece of an insulating material covered with a layer of a material having a high resistivity.

8. An electrostatic machine according to Claim 3, 4 or 5, in which the conducting electrodes are mounted on a common, insulating support and are electrically connected together by a layer of semi-conducting material deposited on the surface of the said support and also covering the conducting electrodes.

9. An electrostatic machine according to any of the preceding claims, in which the dielectric conveyor member is bell-shaped, the conducting electrodes and ionising and collecting elements being respectively mounted on either side of the lateral wall of the said bell-shaped member and being carried respectively by continuous cylindrical supports, the support of the conducting electrodes forming the potential gradient member.

10. An electrostatic machine according to any of the preceding claims, in which the ionising and collecting elements are formed of at least one metal wire extending perpendicularly to the direction of movement of the conveyor member.

11. An electrostatic machine according to any of the preceding Claims 1 to 9, in which the ionising and collecting elements are formed of at least one metal blade extending perpendicularly to the direction of movement of the conveyor member and arranged perpendicularly to the surface of the said conveyor.

12. An electrostatic machine according to any of the preceding claims, in which the space between the conducting electrodes and the conveyor at the side thereof opposite to the ionising and collecting elements is filled with a dielectric fluid medium having a high dielectric strength, which may be different from the fluid medium at the opposite face of the conveyor.

13. An electrostatic machine according to any of the preceding claims, in which the whole machine is enclosed in a sealed envelope filled with substantially pure nitrogen or substantially pure hydrogen under pressure.

14. An electrostatic machine, substantially as described with reference to Figs. 1 to 4 of the accompanying drawings.

15. An electrostatic machine, substantially as described with reference to Figs. 5 and 6 of the accompanying drawings.

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Fig.1

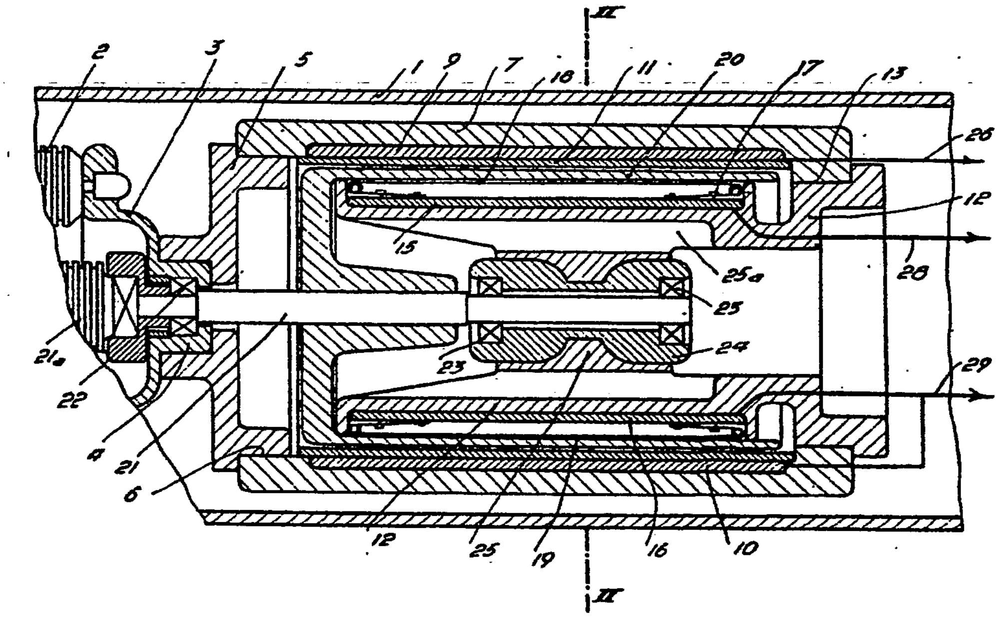
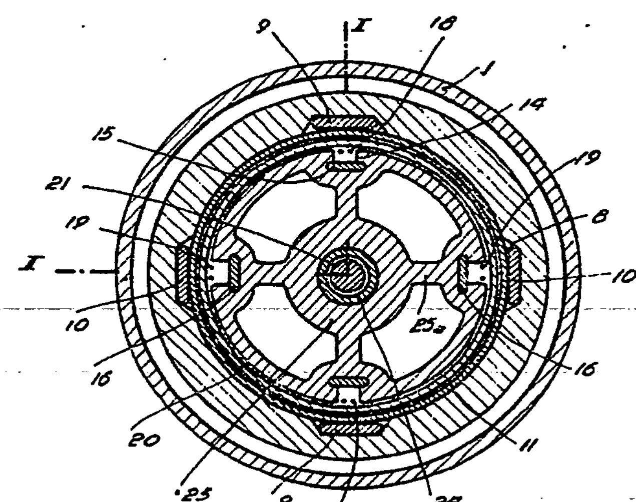


Fig.2



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SHEETS 1 & 3

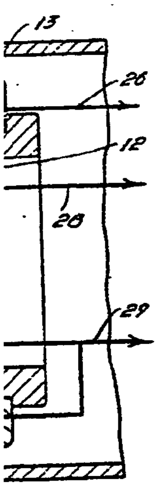

Fig. 5

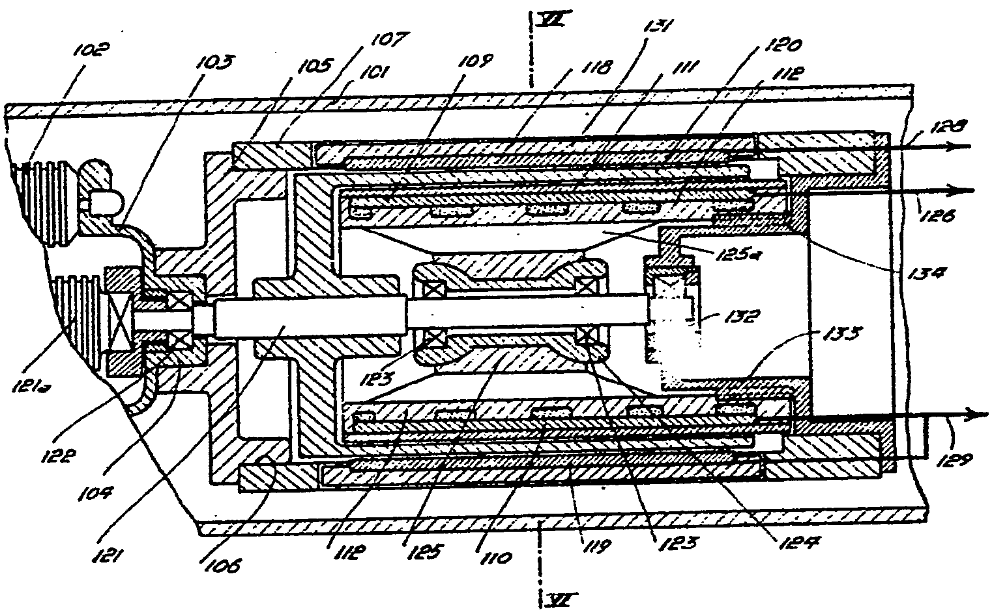

Fig. 6

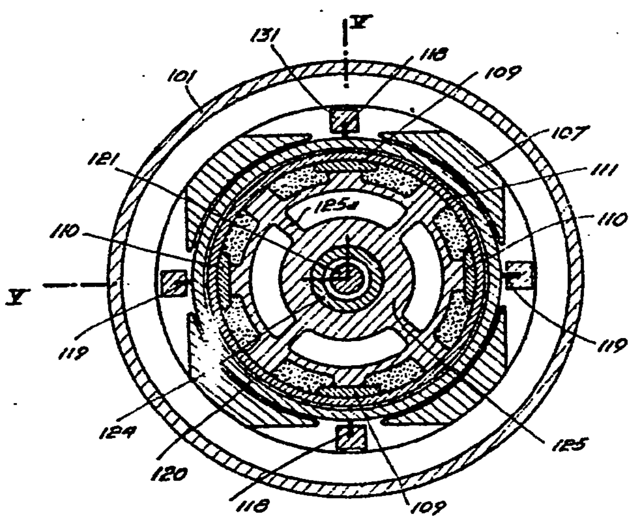

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Fig.1

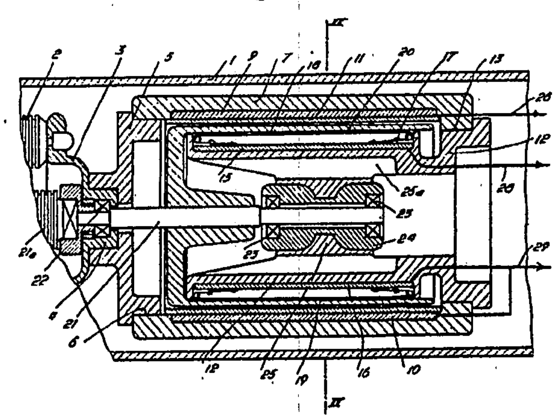

Fig.5

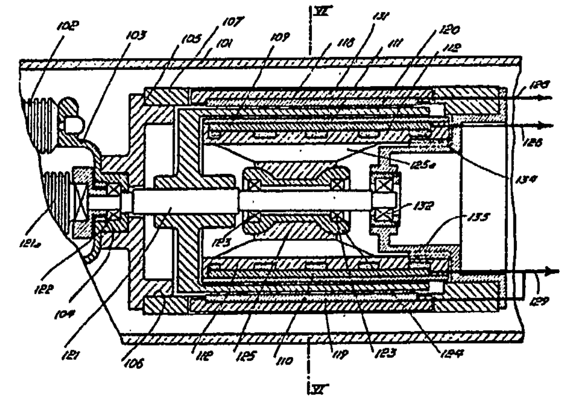

Fig.2

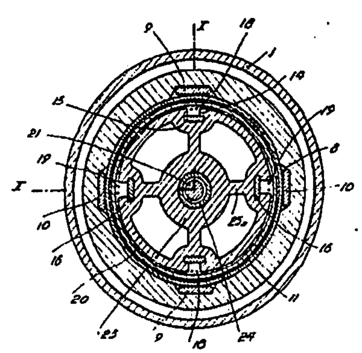

Fig.6

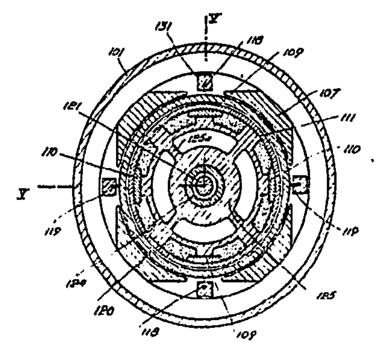

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Fig. 3

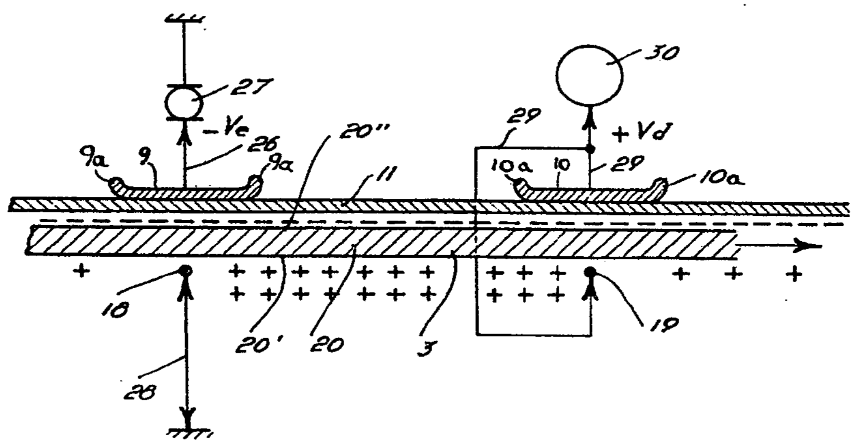
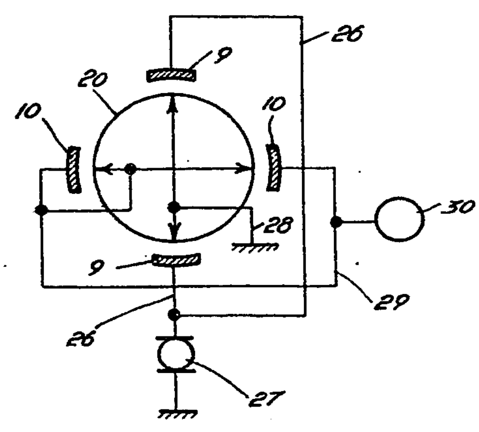


Fig. 4



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